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ORIGINAL ARTICLE

Lumbar epidural space was narrower in parturients than that in nonpregnant women by ultrasound assessment

藉由超音波輔助確定產婦之硬脊膜外腔較非孕婦狹窄

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Abstract Labor epidural is commonly used to provide both regional anesthesia and postoperative pain relief. Epidural space is supposed to be narrower and deeper in a parturient than that in a nonpregnant woman. The aim of this study was to explore the difference of epidural spaces between parturient and nonpregnant women by ultrasound assessment. Thirty nonpregnant female volunteers and 30 parturients undergoing labor epidurals were enrolled to receive ultrasound examination. A low-frequency (2–5 MHz) curved-array ultrasound probe was used to obtain spinal sonoanatomy for each subject. The longitudinal paramedian scanning plane was used to obtain optimal ultrasound image for spinal sonoanatomy. Primary outcome was evaluated by the diameter and depth of epidural space at three lumbar interspaces (from L2 to L5). The quality of ultrasound images was also compared between the groups by a numerical scoring system (from 0 to 3). The mean diameters of lumbar epidural spaces were 3.03 ± 0.45 mm and 4.44 ± 0.49 mm ($p < 0.05$) for parturients and nonpregnant women,

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respectively. The mean depths of lumbar epidural spaces for parturients and nonpregnant women were 3.53 ± 0.62 cm and 3.25 ± 0.63 cm, respectively ($p < 0.05$). The mean scores for epidural space image quality were 2.58 ± 0.58 and 2.63 ± 0.53 for parturients and nonpregnant women, respectively ($p = 0.08$). Epidural space is narrower and deeper at lumbar interspaces in obstetrics by ultrasound examination. The quality of ultrasound images did not differ significantly between the groups. These quantitative results improve the understanding of the differences between two groups that have been previously known qualitatively and may help in avoiding complications.

摘要 腰椎硬脊膜外阻斷術常用於產婦之減痛分娩及剖腹產之麻醉與術後止痛，一般認為產婦的硬脊膜外腔會比非懷孕女性較窄且較深，因此增加硬脊膜外阻斷術的困難度。本研究目的在於探討，在超音波掃描下懷孕與非懷孕婦女之腰椎解剖構造的差異，以期協助硬脊膜外阻斷術之操作。30名產婦及非懷孕的女性自願者接受超音波檢測，以低頻超音波探頭檢測受測者之腰椎第二到三節、第三到四節，及第四到五節之解剖構造。使用超音波從中線側掃描，測量每一節之間硬脊外腔的間距以及從表皮至硬脊外腔的深度，並觀察每一節間超音波影像的品質，以四等分法，再以兩組的結果來加以分析。懷孕者與非懷孕者的腰椎硬脊膜外腔的深度分別為3.53 ± 0.62以及3.25 ± 0.63($p < 0.05$)公分。懷孕者與非懷孕者的腰椎硬脊膜外腔的間距分別為3.03 ± 0.45以及4.44 ± 0.49($p < 0.05$)公厘。懷孕者與非懷孕者的超音波影像的品質分數分別為2.58 ± 0.58以及2.63 ± 0.53($p = 0.08$)。在超音波檢測下證實孕婦的腰椎硬脊膜外腔較窄且較深，而兩組之間的超音波影像品質並沒有明顯的差異。本文以量化的方式來增進對產婦及非孕婦之間硬脊膜外腔解剖差異的了解，期能藉由超音波的輔助下，減少併發症的產生。

Introduction

Epidural block is widely used for obstetric anesthesia and analgesia, although anesthesiologists are sometimes unsuccessful at performing this procedure, and the reported failure rate has ranged from 2% to 20% [1]. Parturients may have unfavorable conditions for epidural block, such as unobvious spinal process landmark, because of obesity or edema, general loosening of soft tissue, deeper epidural space, abnormal sonoanatomy of the ligamentum flavum (LF) and diminished safety zone (epidural space) between LF and dura [2]. Besides, the epidural space is usually detected by a blind technique, "loss of resistance."

Recently, there has been increased interest in the use of ultrasound to guide peripheral and central neuraxial blocks. Although an ultrasound imaging for central neuraxial block is complicated by the surrounding bony structure [3], the spinal sonoanatomy could be more easily detectable with modern ultrasound unit [1,4–7]. Its utility for either prepuncture evaluation or real-time guidance has been reported to improve puncture quality or learning curves for central neuraxial block [8,9]. The depth of epidural space and its related demographic factors have been demonstrated recently [10]. The diameter of epidural space is supposed to be narrower in parturients, but the actual diameter was not calculated in previous studies because of inadequate resolution of ultrasound images [11]. Awareness of the actual average epidural diameter can possibly reduce the complication of the procedure.

The aim of the study was to evaluate the differences of epidural space between parturients and nonpregnant women by a modern ultrasound unit in real time. We intended to measure the diameter of epidural space (safety zone) in a prospective, controlled method.

Materials and methods

The study was approved by the Institutional Review Board of Kaohsiung Medical University Hospital and the ClinicalTrials.gov. Written, informed consent was obtained from each parturient and volunteer. A standardized protocol was used for all subjects, and all procedures were carried out between June 2008 and January 2009. We enrolled 30 parturients and 30 healthy, young female volunteers as a control group. The parturient group included all nulliparous women who were scheduled to receive lumbar epidurals for elective caesarean delivery or labor analgesia. Subjects of the two groups were eligible for the study if they were ASA (American Society of Anesthesiologists) physical status classification system I or II, had body mass index (BMI) between 25 kg/m^2 and 30 kg/m^2, and were between 20 years and 45 years of age. The exclusion criteria were clinically obvious or known spinal deformity, previous spinal surgery, or any contraindication to epidural analgesia. Our setting was an anesthesia department of a teaching medical center with an annual caseload of more than 14,000 anesthetics, with 20% performed under regional anesthesia.

As per standard protocol, subjects were placed in left lateral decubitus position before ultrasound scanning. The subjects' shoulders and hips were both positioned perpendicularly to the bed. The subjects' knees were drawn to the chest, the neck was flexed, and they were instructed to actively arch the back outward. Recorded physical characteristics included age, height, weight (before and after pregnancy), gestation age of parturients, and grades of spinal landmarks. The grades were defined as follows: Grade 1 = spinal processes are visible; Grade 2 = spinal processes are not seen but easily palpated; Grade 3 = spinal processes are not seen and not palpated but the interval between them is palpated as a low landmark under the thumb; and Grade 4 = none of the previous cases [2]. The BMI of each subject was also calculated.

We used a Micromaxx ultrasound system (Sonosite Inc., Bothell, WA, USA) with tissue harmonic imaging capabilities. A curved-array transducer (2—5 MHz with Micromaxx system) was used for the scan. Ultrasound scanning (US) was preformed in the longitudinal paramedian plane [12] by a single investigator, who was experienced in US imaging of the spine and familiar with spinal sonoanatomy. The transducer was held in the nondominant hand of the operator, and it was positioned 1—2 cm lateral to the spinal processes. Using the ultrasound images, the optimal vertebral levels (L2/L3, L3/L4, and L4/L5) were identified. The typical longitudinal paramedian view of lumbar spinal sonoanatomy depicted the erector spinae muscle, lamina, LF, dura, and vertebral body (VB) (Fig. 1).

Data were collected by a study-blinded investigator, who was also familiar with spinal sonoanatomy. Under the typical ultrasound image of spinal sonoanatomy, the investigator froze the screen and measured the variables from the ultrasound software. The epidural space diameter (perpendicular distance from the LF to the dura) and epidural depth (perpendicular distance from the skin to the inferior border of LF) were measured. The visibility of lumbar epidural space (including LF and dura) under ultrasound images was also evaluated by a numerical scoring system (0 = none, 1 = hardly, 2 = well, 3 = very well detectable). The total number of analyzed ultrasound data in each group was 90 because of three examined lumbar interspaces for each subject. Data of three lumbar interspaces were pooled for calculation.

Continuous variables, presented as means ± standard deviation, were analyzed using the Student's *t*-test. Nonparametric data, presented as medians and range, were analyzed using the Mann—Whitney *U* test. Categorical data were presented as numbers and percentages, and were analyzed using the Chi-squared statistic and the two-sided Fisher's exact test as appropriate. A *p* value less than 0.05 was considered significant. Commercial SPSS 10.0 software for Windows (SPSS, Inc., Chicago, IL, USA) was used for data analysis.

Results

All 60 subjects underwent complete ultrasound examinations for three lumbar interspaces. The physical characteristics of parturients and volunteers are presented in Table 1. The characteristics of parturients before pregnancy and spinal landmark grade did not differ significantly from those of the volunteers.

We observed that the mean diameter of epidural spaces for parturients and volunteers at lumbar interspaces were 3.03 ± 0.45 mm and 4.43 ± 0.49 mm ($p < 0.001$). The mean depths of epidural spaces for parturients and volunteers at lumbar interspaces were 3.53 ± 0.62 cm and 3.25 ± 0.63 cm, respectively ($p < 0.05$). Epidural spaces were very well detectable in 57 (63.3%), well detectable in 29 (32.2%), and hardly detectable in 4 (4.5%) of 90 examinations for parturients. Epidural space was very well detectable in 61 (67.8%), well detectable in 27 (30%), and hardly detectable in 2 (2.2%) of 90 examinations for volunteers. The mean scores for epidural space image quality were 2.58 ± 0.58 and 2.63 ± 0.53 for parturients and volunteers, respectively ($p = 0.08$) (Table 2).

Discussion

The performance of neuraxial block is technique demanding, especially in obstetrics. Pregnancy-associated

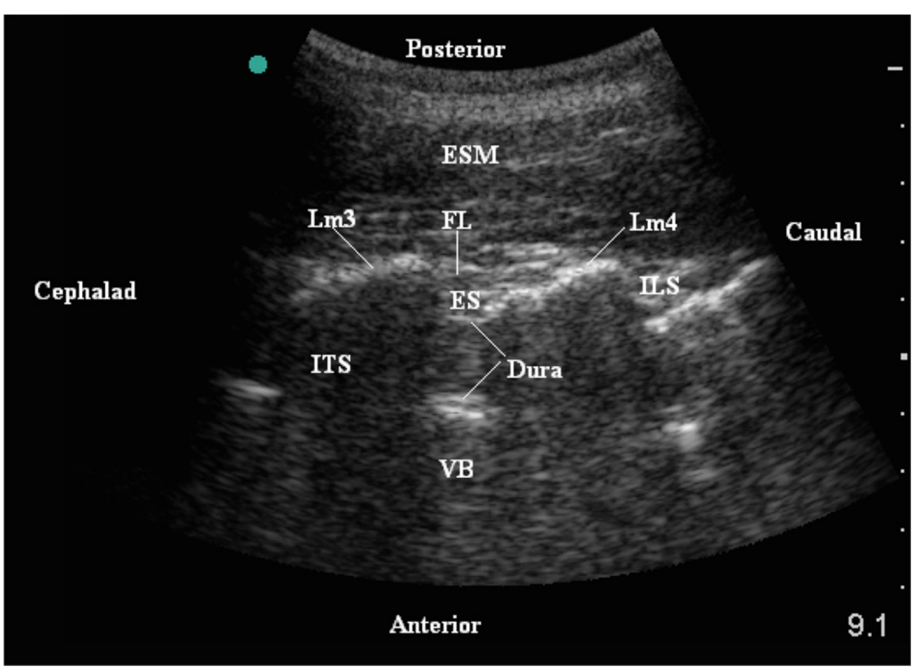

Figure 1. Longitudinal paramedian scanning plane of the lumbar spine. This graph depicts a typical spinal sonoanatomy of a young nonpregnant woman. ES = epidural space; ESM = erector spinae muscle; ILS = interlamina space; ITS = intrathecal space; LF = ligamentum flavum; Lm = lamina; VB = vertebral body.

Table 1 Characteristics of subjects who underwent ultrasonographic assessment of spinal anatomy

Characteristics	Parturients ($n = 30$)	Volunteers ($n = 30$)	p
Age, yr	31.9 ± 3.6	31.5 ± 4.5	0.66
Height, cm	158.9 ± 5.9	159.5 ± 3.9	0.82
Weight, kg			
Before pregnancy	53.3 ± 8.7	51.5 ± 5.9	0.55
During delivery	66.7 ± 10.4	NA	
Body mass index, kg/m^2			
Before pregnancy	20.7 ± 3.4	20.2 ± 1.63	0.46
During delivery	26 ± 3.8	NA	
Gestation age, wk	38.3 ± 1.2	NA	
Spinal landmark grade, n (%)			0.12
1	6 (20)	11 (36.7)	
2	19 (63.3)	18 (60)	
3	5 (16.7)	1 (3.3)	
4	0	0	

Values are expressed as mean ± standard deviation.
NA = not applicable.

weight gain and tissue changes result in significant changes in spinal anatomy [11], and the identification of the epidural space becomes more difficult. These anatomical changes frequently cause multiple attempts to locate the epidural space. Previous evidence suggests that it increases the risk of complications [13]. Failures and complications of regional anesthesia can be related to many causes, one of the most important being the blind nature of such techniques. Several techniques, regimens, and equipments have been proposed to facilitate the search for the epidural space. Prepuncture epidural space localization by ultrasonography has been previously described [2,14,15]. This indicates that ultrasonography can be a valuable guide for epidural puncture in obstetrics.

In this study, we examined the lumbar spine of 60 individuals by ultrasound. We compared the diameter and depth between parturients and nonpregnant volunteers by the longitudinal paramedian approach. Our primary outcome showed that the epidural spaces were significantly narrower and deeper in parturients than nonpregnant women at lumbar interspaces in the Chinese population. The mean diameter of epidural space (safety zone) in a parturient was 68.4% (3.03/4.43) of that of nonpregnant women. Parturients might be prone to unintentional dural puncture because of narrower safety zone. These quantitative results improve the understanding of the differences between two groups that have been previously known qualitatively and may help in avoiding complications.

Although in a previous study, Grau et al. [11] had mentioned that the epidural space was narrower during pregnancy, owing to the limitation of resolution, they indicated that the quality of the sonographic depiction of the key structure was reduced by pregnancy. The spinal process landmark is supposed to be less obvious after pregnancy. This study did not actually measure the diameter of the epidural space. In our study, we not only measured the diameter of the epidural space but also compared the imaging quality of spinal sonoanatomy. In our study parturients, the spinal process landmark did not become significantly less obvious after weight gain (from 53.3 kg to 66.7 kg) and BMI change (from 20.8 kg/m^2 to 26 kg/m^2). Their spinal landmark grade increased but not significantly compared with that of nonpregnant women. Most subjects (>90%) had very well detectable spinal sonoanatomy (epidural space) in both groups. The mean scores for epidural space image quality

Table 2 The comparison of spinal sonography between parturients and volunteers

Parameters of sonography	Parturients ($n = 30$)	Volunteers ($n = 30$)	p
Diameter, mm	3.03 ± 0.45	4.44 ± 0.49	<0.001
95% CI (range)	2.93–3.12 (2.4–4.4)	4.33–4.53 (3.5–5.3)	
Depth, cm	3.53 ± 0.62	3.25 ± 0.63	0.013
95% CI (range)	3.35–3.71 (2.41–4.96)	3.12–3.38 (2.26–4.77)	
Image quality (0–3)	2.58 ± 0.58	2.63 ± 0.53	0.080

The analyzed data included diameter, depth, and image quality of lumbar epidural space. Data of epidural space are expressed as mean ± standard deviation.
The differences of epidural diameter and depth were significant when the parturients were compared with volunteers.
CI = confidence interval.

were similar for parturients (2.58) and volunteers (2.63). Two factors can explain the discrepancy of this result. Both image quality and window were improved, and they were important for spinal sonoanatomy. Using up-to-date ultrasound equipment and the paramedian approach, the spinal anatomy was easily identified.

Ultrasonography has gained more popularity in daily anesthetic practice for both vascular access and regional anesthesia [3,8,16,17]. Spinal sonoanatomy is complicated by the surrounding bony structure, but the use of a modern ultrasound machine is a promising technique to obtain better image quality of the spinal sonoanatomy and assist neuraxial blocks [11,18]. We have achieved continuous improvement in ultrasound imaging technology for spinal sonoanatomy. The development of the Micromaxx ultrasound system with tissue harmonic imaging capabilities can give an accurate reading of the depth, localization, and structures of the epidural space in real time. Using the Micromaxx ultrasound system, we demonstrated comparable spinal sonoanatomy quality in both parturients and volunteers in the study.

Typical spinal sonoanatomy consists of two components: the "acoustic shadows" and "acoustic windows." The acoustic shadows result from intense reflection (weakening ultrasound beam) and refraction (distorting ultrasound image) caused by the soft tissue and bone interfaces [19]. They are visualized as black bars. The acoustic windows are obtained from the penetration of ultrasound beam through the softer tissue of the interspaces. They are visualized as parts in spinal sonoanatomy.

Perpendicular ultrasound scans of a vertebral level at both the transverse approach and median longitudinal approach were considered as the classical ultrasonographic approach for spinal sonoanatomy. Compared with the median approach, the paramedian access was reported to provide favorable acoustic shadow/window ratio [2] and to improve the overall visibility of all examined structures. Therefore, we used the paramedian longitudinal scan in the method.

There are several limitations in the study. First, the depth of epidural space was measured perpendicularly without consideration of oblique trajectory along the lamina. Therefore, the depth during real puncture might be underestimated. Second, no real puncture was performed in the volunteers; therefore, the real epidural depths between parturients and nonpregnant women could not be compared. Third, the study was designed as an observational study. We did not have a double-blind design, because a single anesthesiologist performed ultrasound examinations and ultrasound-derived measurements.

In conclusion, the epidural space (safety zone) was significantly narrower and deeper in parturients than nonpregnant women at lumbar interspaces in the Chinese sample population. This might partially explain the technical difficulty in epidural block for parturients. The quality of spinal sonoanatomy of parturients did not diminish because of modern technical improvement. Hence, the prepuncture examination by an ultrasound assessment would also be feasible and valuable for neuraxial block. This may be of benefit in obtaining anatomical images while dealing with anticipated difficult neuraxial blocks.

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